INTERNATIONAL JOURNAL OF ADVANCED BIOLOGICAL RESEARCH

www.scienceandnature.org

CLIMATE CHANGE ADAPTATION OF POTATO (*Solanum tuberosum* L.): INFLUENCE OF BIOZYME® RATE ON POTATO YIELD, QUALITY AND MINERAL NUTRIENT UPTAKE

[a]Karanja, B. K.,[a*]Isutsa, D. K. & [a]Aguyoh, J. N.
[a]Egerton University, P. O. Box 536-20115, Egerton, Kenya
[a*]Chuka University, P. O. Box 109-60400, Chuka, Kenya
[*]Corresponding Author E-mail: dorcaski@yahoo.com

ABSTRACT
Potato *(Solanum tuberosum* L.) is an important food crop worldwide. Growers prefer potato because of its short growing season and tolerance to poor soils. Growers are using different agrochemicals so as to improve tuber yield, quality and maturity period under erratic and unreliable rain patterns. Biozyme® foliar feed is widely used to hasten maturity and enhance yields of crops. Biozyme® is said to be a storehouse of hormones and nutrients that improve the health of a crop. It contains major hormones along with primary and secondary mineral nutrients. This study determined Biozyme® rate that is lower than the commercially recommended 500 ml/ha to curb overuse and misuse, but still enhance potato tuber yields under climate change deficit rainfall adaptation. The study was set up in split plots arranged in a randomized complete block design, replicated three times and repeated once. Main plots were assigned to two contrasting potato cultivars (Tigoni and Asante), while subplots were assigned to Biozyme® rate (0, 125, 250, 500 and 750 ml/ha). Each subplot was planted with 28 seed potato tubers spaced at 30 cm x 70 cm in four rows. A distance of 1 m separated plots. The 750 ml/ha Biozyme® significantly ($P<0.05$) increased total potato tuber yields by 3x to 7x, reduced unmarketable tubers by up to 3x, enhanced dry matter by 10% and starch by >2x compared to the 0 ml/ha Biozyme®. The 0 ml/ha Biozyme® produced 2-11 t/ha and 7-14 t/ha in 'Tigoni' and 'Asante', while the 750 ml/ha Biozyme® produced 25-33 t/ha and 39-43 t/ha in 'Tigoni' and 'Asante', respectively. The 750 ml/ha Biozyme® also increased leaf tissue N by >1%, P by >100 ppm and K by > 9 ppm in both seasons and cultivars. The difference in performance for 500 and 750 ml/ha Biozyme® was always not significant ($P>0.05$). Thus, it is not advisable to foliar-feed potato plants using Biozyme® rates exceeding 500 ml/ha since this will amount to overuse and misuse and exacerbate tuber perishability. Slightly lower Biozyme® rates than 500 ml/ha may be recommended to guarantee production of "hardier" potatoes ideal for safe handling.

KEY WORDS: Biostimulant, Dry matter, Foliar feed, Food security, Perishable, Potato tubers, Starch accumulation.

INTRODUCTION

Potato *(Solanum tuberosum* L.) is one of the most important food and cash crops in many countries (Khurana et al., 2003; Muthoni and Nyamongo, 2009). Most Kenyan growers prefer potato due its short growing season and tolerance to poor soils over maize, which requires longer growing time and more fertile soils. Erratic and unreliable rain pattern has prompted growers to search for agronomic practices that would hasten growth of potato tubers to utilize the limited rains available. The challenge of rain deficit has resulted in overuse and misuse of Biozyme® to hasten growth and enhance yields of potato. The overuse and misuse results in oversupply of highly succulent potatoes that rot rapidly and heavily in storage and markets. Cognizant of this negative attribute of Biozyme®, buyers end up rejecting potatoes produced using Biozyme®. The rejection works against the growers through the incurred massive income losses. Biozyme® is biologically derived from *Ascophylum nodosum* seaweed through a special fermentation (Biostadt.com, 2008). The dried granulated seaweed powder is a mixture of animal and plant origin; products undergo high-tech fermentation process through lactobacilli to yield free natural nutrients to be used as liquid biofertilizer for foliar application. Fermentation helps ensure richness of free vital elements and thus faster absorption by plant tissues. Biozyme® is said to be a storehouse of hormones and nutrients (Biostadt.com, 2008). The fermented seaweed releases enormous energy in the form of soluble nutrients, making them available to the plant. Biozyme® is said to stimulate crop growth at all critical stages through provision of hormonal and nutritional support, including cytokinins, auxins, enzyme-hydrolysed proteins, betaines, primary and secondary nutrients.

Biozyme® is highly attractive because it is an eco-friendly, non-toxic, non-chemical organic storehouse of naturally occurring substances that influence plant physiological systems at very low concentrations. It contains elements that help in cell growth and breakdown of complex molecules into simpler ones, easily utilized by the plant. Biozyme® is thus a natural plant food, which can be applied as a foliar feed, soil feed, root dip, seedling dip or seed treatment (Biostadt.com, 2008). These applications enable plants to receive direct benefits from naturally balanced nutrients and growth stimulating substances, especially at the time of differentiation and

development to promote seed germination, frame and biomass development, vegetative growth, carbon: nitrogen ratio differentiation, reproductive growth and maturity. Biozyme® is recommended to be applied to coincide with all critical stages in crop life cycle. Application at early crop stages results in strong, sturdy and healthy plants (Biostadt.com, 2008) through early germination, vigorous seedling growth, root mass growth, optimum nutrient uptake, increased soil microbial activity and better foliage. At establishment, it promotes healthier plants, profuse branching/tillering, greater flower/fruit retention, enhanced immune system, optimum input uptake and production. At reproductive stage it significantly increases high quality produce. Single application (15 to 20 days after first application) is recommended for optimum results (Biostadt.com, 2008).

Tuber formation and number is affected by many factors, including temperature, photoperiod, moisture, soil conditions and nutrient availability (Vandam et al., 1996). All growth stages of potato, but particularly tuber formation, are very sensitive to water deficit stress (Thornton (2002; Shock et al., 2006). However, the critical period in potato is during tuber development and achieving better yields requires adequate water supply from its beginning until ripening (CIP, 2007). During tuberisation adequate moisture is necessary to prevent common scab symptoms (Yuan et al., 2003). Generally potato has a shallow root system, and this is largely the reason for its inability to penetrate restrictive layers. Potato root system, irrespective of the distribution of roots in the soil, is poor at extracting soil water at deep depths, and that the fine and fibrous nature of the root system contributes to this. Potato plants wilt at times of high evaporative demand of water even when the soil is irrigated to field capacity, presumably because of resistance to water flow in the root system (Lesczynski and Tanner, 1976; Stahlman and Allen, 2001). Potato is particularly sensitive to soil water stress, which affects physiology, bulking, grade, specific gravity, processing quality and yield of tubers (Shock et al., 2006; Thompson et al., 2007). Potato tuber response to soil moisture conditions begins before tuber set. Increased water stress duration before tuber initiation reduces tubers set per stem (MacKerron and Jefferies, 1986). The present study determined whether Biozyme® foliar feed rate that is lower than the commercially recommended one could enhance potato tuber yields under deficit rainfall to adapt to climate change and curb overuse and misuse that produces highly perishable potatoes.

MATERIALS &METHODS

Research Site and Experimental Design

An experiment was conducted on a farm at 0°23' South, 35°35' East and 2238 meters above sea level. The farm normally receives 908 to 1012 mm rainfall per annum and 16 to 23°C temperature. The soils on the farm were well-drained sandy loam-vintric mollic Andosols (Jaetzold and Schmidt, 1983). Grade II certified 'Asante' and 'Tigoni' seed potato tubers, measuring 45 to 65 mm in diameter, were obtained from the Agricultural Development Corporation Potato Project Centre and Biozyme® foliar feed was bought from an agrochemical shop. The experimental field measured 50 m by 20.8 m. Each main plot measured 23.5 m by 7.6 m and was subdivided into sub-plots, measuring 5.6 m by 3.5 m each. Each experimental unit had 28 tubers in four rows. A 1-m path separated plots. Main plots were assigned to the two contrasting potato cultivars (Tigoni and Asante). 'Asante' is best for crisping while 'Tigoni' is good for making chips. Subplots were assigned to Biozyme® rate (0, 125, 250, 500 and 750 ml/ha). Each rate of Biozyme® foliar feed was applied twice, at the 6^{th} - 8^{th} leaf stage and at flowering stage, according to manufacturer's recommendation. A polythene sheet was erected between plots on the day of foliar-feeding to prevent drifting of Biozyme® to adjacent plots.

Maintenance of the Experiment

Land was cleared of weeds followed by ploughing, harrowing and pulverizing the soil to at least 20 cm depth. Beds raised 20 cm from the ground level were constructed in the land. Potato tubers were kept in a humid store with diffuse light to break dormancy and sprout. Dormancy was considered broken when sprouts, measuring 1.5 - 2.5 cm long were attained. Tubers were planted at a spacing of 70 cm x 30 cm. Tubers were planted at a depth of 5 – 10 cm (Lung'aho et al., 2007) with dominant sprouts facing upwards for faster and uniform emergence. All potato tubers were planted with 200 kg/ha (0.392 kg/subplot) DAP and 2.5 t/ha (4.9 kg/subplot) farmyard manure (Kabira, 2002), according to farmers' practice. After establishment potato plants were weeded regularly up to 6 weeks after planting when they could suppress weeds. Ridging was done at two and four weeks after potato flowering to 25 cm height (Lung'aho et al., 2007) to prevent greening of exposed tubers, infestation by potato tuber moths, and internal brown spot caused by high soil temperature (CIP, 2000). Irrigation was done using drip tubes during early and late hours of the day to reduce evaporation. Plots were irrigated to maintain moisture content at field capacity (Gawroska *et al*., 1992; Thornton et al., 1996). Spraying was done to prevent late blight (*Phytophthora infestans*) using 3 kg/ha Ridomil in a 15-litre knapsack sprayer. Spraying was repeated twice a week under wet conditions. Insecticides Dimethoate and Alphacypermethrin, at 15 g/L and 100 g/L, respectively, were added to the fungicide whenever aphids, whiteflies, mites and other harmful insects were observed.

Data Collection

Ten central plants per experimental unit were selected, tagged and used for data collection. Soil, leaf tissue and tuber samples were taken at the end of each season for selected macronutrients determination (Okalebo et al., 2002). Potato tuber yield was assessed by taking the average of 10 hills per plot. The tubers were graded into rotten, ware (>65 mm), sett (28 - 65 mm) and chat (<28 mm) categories (Lung'aho et al., 2007). Healthy potato tubers were further graded according to their weight using an Elite Electronic Scale Model 3001 with an accuracy of ±1 g. Potato tubers more than or equal to 50 g were considered marketable, while rotten, diseased, insect-attacked, deformed and those having weight less than 50 g were categorized as unmarketable.

Yield was recorded as total and marketable tuber yield. Starch content and dry matter (DM) of a 3-5 kg sample of

tubers per treatment was determined at harvest on the principle of a linear relationship between specific gravity with starch and/or DM. Percentage DM = 158.3 x -142, while starch content = 112.1 x -106.4; where x = specific gravity (Kawano et al., 1987). Specific gravity was computed by weighing 3-5 kg tuber sample in a sturdy wire basket, both in air (Wa) and in water (Ww) using a spring balance and calculated as: Specific gravity = Ww/(Wa-Ww). Dry matter is an important parameter of potato quality, as it influences sensory attributes (Taylor et al., 2007). Data were subjected to analysis of variance and where the F-test was significant (P<0.05), means were separated using the Duncan's Multiple Range Test (DMRT) at $\alpha = 0.05$. Regression analysis was done to establish relationships among variables.

RESULTS

Effects of Biozyme® Rate on Yield Components of Potato Cultivars

The Biozyme® foliar feed significantly (*P<0.05*) increased total potato tuber yields for both cultivars. The highest rate of foliar feed (750 ml/ha) had 86% and 96% more marketable tubers than the control rate in seasons 1 and 2, respectively (Table 1). 'Asante' had higher marketable tubers than 'Tigoni' by 53% and 30% in seasons 1 and 2, respectively (Table 1).

TABLE 1: Influence of Biozyme® rate on marketable, unmarketable and total tuber yields (t/ha)

	Biozyme® (ml/ha)	Marketable tubers	Unmarketable tubers	Total tubers
Season 1				
'Asante'	0	5.41ef*	1.89a	7.30e
	125	16.70c	1.79a	18.56c
	250	21.70b	1.98a	23.69b
	500	36.92a	1.48ab	38.40a
	750	38.89a	0.44bc	39.32a
'Tigoni'	0	1.00f	1.42ab	2.43f
	125	8.97de	1.40ab	10.37de
	250	12.82cd	0.73bc	13.55d
	500	22.63b	0.63bc	23.26b
	750	25.28b	0.18c	25.46c
Season 2				
'Asante'	0	10.46f	3.95a	14.41ef
	125	19.29de	3.67a	22.96cde
	250	25.59bcd	2.53b	28.15bc
	500	40.90a	2.04bc	42.92a
	750	42.22a	1.15cd	43.38a
'Tigoni'	0	8.80f	2.57b	11.38f
	125	13.68ef	2.55b	16.24def
	250	22.76cd	1.93bc	24.7bcd
	500	42.22c	1.21cd	32.30b
	750	32.36b	0.85d	33.21b

*Means followed by the same letter(s) within a column of each season are not significantly different (*P<0.05*) according to DMRT

Generally, the 750 ml/ha Biozyme® foliar feed resulted in less unmarketable tubers in both seasons. The reduction was 18% and 30% compared to control in seasons 1 and 2, respectively. 'Tigoni' had less unmarketable tubers by 43% and 32% than 'Asante' in seasons 1 and 2, respectively (Table 1). There was a significant (P<0.05) positive increase in total tuber yield with the increase of Biozyme® rate in seasons 1 and 2 (Figure 1). 'Asante' had higher yields with 750 ml/ha of Biozyme® in the two seasons.

Response of the various growth parameters measured depended on the season of potato production, cultivar of potato, and Biozyme® rate applied to the potato plants. The first season, which coincided with low rains (428 mm) proved unfavourable for potato production since the total tuber yields were lower by 4.06 to 7.75 t/ha than those of the second season that coincided with a period of high rains (618 mm).

The temperature conditions were warmer in the first season 17.6 to 22.8^{o}C than in the second season 16.6 to 21.2^{o}C. Warmth reduces potato tuberisation than cold conditions. Holding all other factors constant, these two conditions (low rains and warm temperatures) could explain the lower tuber yields in season 1 compared to season 2.

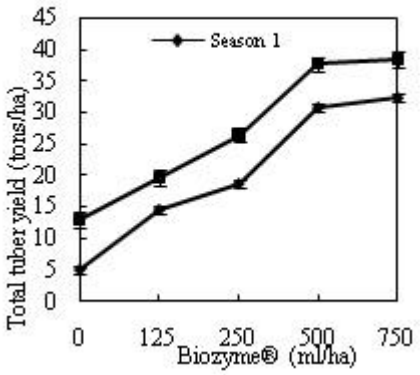

FIGURE 1: Effects of Biozyme® rate on yield of potato cultivars in seasons 1 and 2

In this research, the highest total tuber yield of 43.38 t/ha was for 'Asante' treated with 750 ml/ha in season 2. This indicated that Biozyme® improved the yield of potato plants probably through promotion of robust growth. Biozyme® contains hormonal substances, enzymes, betaines and nutrients, which increase resource

mobilisation to developing parts of plants. Such results were observed by Arthur et al., (2003), who reported an increase in yield on pepper plants treated with Biozyme®. Hormonal cytokinins promote plant cell division, growth, differentiation, and physiological processes. Cytokinins increase chlorophyll content and hence enhance photosynthetic activity. Cytokinins also delay senescence, enabling the plant to remain green longer and ensure continuous flow of carbohydrates for developing fruits and wood formation (Biostad.com, 2008). Hormonal auxins induce cell elongation and development. Auxins and cytokinins act antagonistically during tuber formation; auxins decrease and cytokinins increase accumulation of starch (Yutaka et al., 2002). Enzyme-hydrolysed proteins induce faster and vigorous development of root mass and deep root growth, ensuring that plants cope better with environmental stresses. Betaines reduce intensity of oxidative reactions that damage cell structure and hence enhance crop growth, limit stress and improve overall health of a plant. Biozyme® primary and secondary nutrients (Mg, Fe, B, Mn, Zn, Cu, and Mo) provide nourishment required for healthy plant development Anonymous, 2009). Biozyme® contains nutrients that are naturally chelated and readily assimilated by plants to improve cell division and enlargement, chlorophyll content and plant natural self-defense against pest pressure.

TABLE 2: Influence of Biozyme® rate on total, chat, set and ware tubers in seasons 1 and 2

		Number of tubers per hill			
	Biozyme® (ml/ha)	Ware tubers	Sets	Chats	Total tubers
Season 1					
'Asante'	0	6.49bc*	3.92abcd	1.63a	12.04a
	125	8.58abc	3.84abcde	1.01abc	13.43a
	250	11.26abc	2.54cde	0.91abc	14.71a
	500	14.28ab	1.62e	0.81abc	16.71a
	750	13.84d	1.78de	0.61abc	16.23a
'Tigoni'	0	5.06c	6.16a	1.21ab	12.43a
	125	7.01abc	5.25ab	0.6abc	12.86a
	250	7.65abc	4.45abc	0.68abc	12.78a
	500	10.48abc	4.27abc	0.21c	14.96b
	750	11.4abc	3.67bcde	0.22bc	15.29c
Season 2					
'Asante'	0	7.51de	2.97a	2.57a	13.05cd
	125	11.82abcde	2.53a	2.1ab	16.44abcd
	250	17.03abc	1.64a	1.61ab	20.28abc
	500	20.19a	0.52a	1.23ab	21.93ab
	750	20.65a	0.78a	1.26ab	22.68a
'Tigoni'	0	5.78e	4.03a	2.1ab	11.91d
	125	10.27cde	3.14a	1.78ab	15.2bcd
	250	14.35abcd	2.52a	1.12ab	18abcd
	500	18.39ab	2.01a	0.67b	21.07ab
	750	18.55ab	1.64a	0.67b	20.85ab

*Means followed by the same letter(s) within a column of each season are not significantly different (*P<0.05*) according to the DMRT.

Total, Ware, Set and Chat Tubers per Hill as Influenced by Biozyme® Rate

Total and ware tubers increased significantly (*P<0.05*) with Biozyme® rate in seasons 1 and 2. The 750 ml outperformed control rate in total number of tubers by 27% and 60% in seasons 1 and 2, respectively. 'Asante' had more tubers than 'Tigoni' in both seasons. The highest rate of Biozyme® foliar feed had 53.3% and 63% more ware tubers as compared to control Biozyme® in seasons 1 and 2.

Sets and chats decreased significantly (*P*<0.05) with increase in Biozyme® foliar feed rate. When averaged across the tested potato cultivars, 750 ml/ha of foliar feed had the least number of sets and chats in seasons 1 and 2. Compared to the control, 750 ml/ha Biozyme® foliar feed had less sets by 42.72% and 65.42% in seasons 1 and 2, respectively, and less chats by 70.12% and 59.89% in seasons 1 and 2, respectively (Table 2).

In this study, Biozyme® treated plants had significantly (*P*<0.05) enlarged potato tubers as compared to control plants. Biozyme® treated potato plants yielded more ware potato tubers and also had less number of chats per hill as compared to Biozyme® untreated potato plants. This result was probably because of the enhanced resource mobilisation to the tuber sinks by auxins in the Biozyme®. Auxins are hormonal substances responsible for bigger cells and increased cell division in roots. These changes in turn result in enlarged tubers and hence more ware tubers and marketable yields (Rayorath et al., 2008).

Dry Matter and Starch Content Percentages of Potato Tubers as Influenced by Biozyme® Rate

There was a significant (*P*<0.05) effect of Biozyme® foliar feed on dry matter content in season 1 (Table 3). The 750 ml/ha Biozyme® foliar feed resulted in the highest tuber dry matter at that time. 'Asante' had higher dry matter content by 10.32% and 13.09% in seasons 1 and 2, respectively, as compared to 'Tigoni'.

Starch content was significantly (*P*<0.05) affected by Biozyme® rate in seasons 1 and 2. The highest starch content (18.67% more than control) was in season 1 for 750 ml/ha Biozyme® foliar feed of Tigoni cultivar (Table 3).

Biozyme® components such as macro- and micro-nutrients, amino acids, vitamins, cytokinins, auxins and abscisic acid, promote cellular metabolism of treated plants, leading to enhanced growth and yields in terms of dry matter and start accumulation (Crouch et al., 1992). Biozyme® enzyme-hydrolysed proteins improve uptake of complex molecules and previously unavailable nutrients and water from soil by plants to be used in enhanced dry matter and starch content biosynthesis and accumulation.

TABLE 3: Effects of Biozyme® rate on percentage dry matter and starch of potato cultivars

		Percentage	
Season 1	Biozyme® (ml/ha)	Dry weight	Starch
'Asante'	0	22.77ab*	13.61e
	125	23.07ab	20.64cd
	250	25.1ab	25.57abc
	500	29.87a	28.81ab
	750	26.4ab	28.90ab
'Tigoni'	0	16.90b	10.58e
	125	22.00ab	15.46de
	250	24.83ab	23.40bc
	500	24.03ab	28.84ab
	750	27.53a	29.25a
Season 2			
'Asante'	0	22.13a	15.62d
	125	22.83a	22.68bc
	250	27.83a	27.63ab
	500	30.05a	30.85a
	750	30.67a	30.95a
'Tigoni'	0	20.37a	13.20d
	125	23.17a	18.13cd
	250	23.17a	26.44ab
	500	24.65a	31.22a
	750	26.70a	31.32a

*Means followed by the same letter(s) within a column of each season are not significantly different ($P<0.05$) according to the DMRT

TABLE 4: Selected properties of soil taken at the end of the experiment

Season 1	Biozyme® (ml/ha)	pH	Total N (%)	P (ppm)	K (ppm)
'Asante'	0	6.12a*	0.95a	40.67a	18.80a
	125	6.15b	1.25a	90.67a	15.87a
	250	6.18c	1.44a	106.67a	21.03a
	500	6.16d	1.91b	162.67b	26.13a
	750	6.15e	2.15c	167.12c	28.17b
'Tigoni'	0	5.81a	0.75a	27.70a	16.53a
	125	6.13b	1.01a	78.33a	13.50a
	250	6.16c	1.34a	95.11a	19.10a
	500	6.17d	1.78b	144.67b	25.80b
	750	6.16e	2.12c	146.67c	27.90c
Season 2					
'Asante'	0	6.15a*	0.95a	34.33a	17.17a
	125	6.17b	1.51a	85.33a	20.50a
	250	5.83b	1.45a	98.33a	25.17a
	500	6.13c	2.11b	154.12b	28.40b
	750	6.13d	2.13c	160.67c	31.30c
'Tigoni'	0	6.13a	0.77a	27.67a	18.07a
	125	6.09b	1.06b	80.67a	14.70a
	250	6.07c	1.15b	97.12a	19.33a
	500	6.03c	1.84c	147.11b	28.67b
	750	5.99c	2.15d	147.33c	33.30c

*Means followed by the same letter(s) within a column of each season are not significantly different ($P<0.05$) according to DMRT

Selected Properties of the Soil Taken at the End of the Experiment

Soil from the experimental plots was subjected to laboratory analysis to determine the pH, total N, P and K contents. Soil pH remained fairly basic in the two seasons. Nearly all pH values were above 6 (Table 4). Total N was not significantly different between Biozyme® rates 125 and 250 ml/ha in both seasons (Table 4). However, from

250 to 750 ml/ha there was a significant (P<0.05) increase in total N and available K in both seasons 1 and 2.

The highest content of P and K was observed for the highest rate of Biozyme® foliar feed in both seasons. Soil pH remained fairly constant, indicating that Biozyme® had no direct influence on it. There was enhanced amount of N, P and K in plots treated with Biozyme® compared to control plots that did not receive Biozyme® foliar feed. Biozyme® enzyme-hydrolysed proteins improve soil microbial activity to break down and release soil-bound mineral nutrients into soil solution for high and easy detection during soil analysis.

TABLE 5: Selected mineral contents of sampled leaf tissue

Cultivar	Biozyme® (ml/ha)	Total N (%)	P (ppm)	K (ppm)
Season 1				
'Asante'	0	0.97a*	55.14a	1.34a
	125	1.44a	82.14a	1.37a
	250	1.96b	158.77b	1.44b
	500	2.13c	169.14c	1.52c
	750	2.17d	192.14d	1.58d
'Tigoni'	0	0.76a	51.14a	1.34a
	125	0.89a	83.23a	1.37a
	250	0.96a	158.43b	1.42a
	500	1.09a	165.29c	1.53b
	750	2.12b	188.13d	1.57c
Season 2				
'Asante'	0	1.04a	58.17a	0.41a
	125	1.73a	87.17a	1.86b
	250	2.15b	161.53b	1.95c
	500	2.34c	178.50c	2.23d
	750	2.47d	196.25d	2.07c
'Tigoni'	0	0.78a	55.02a	1.84a
	125	0.98a	88.35a	1.87a
	250	1.73b	168.43b	1.92a
	500	1.98c	174.57c	2.06b
	750	2.34d	197.64d	2.07c

*Means followed by the same letter(s) within a column of each season are not significantly different (*P<0.05*) according to DMRT

TABLE 6: Selected mineral contents of tubers sampled at the end of the experiment

Season 1	Biozyme® (ml/ha)	Total N (%)	P (ppm)	K (ppm)
'Asante'	0	1.23a*	11.66a	0.81a
	125	1.85b	11.9a	0.88b
	250	1.93c	12.43b	0.91c
	500	1.97d	12.99c	1.01d
	750	2.08e	12.46d	0.78d
'Tigoni'	0	0.54a	8.48a	0.81a
	125	0.84a	8.48a	0.85a
	250	0.98a	9.54a	0.83a
	500	1.08b	10.45b	0.99b
	750	1.69c	10.87c	1.04c
Season 2				
'Asante'	0	1.84a	11.65a	0.82a
	125	1.95a	12.54a	0.96b
	250	2.04a	13.46a	0.82b
	500	2.18a	9.47a	0.91b
	750	2.58b	10.96b	1.19b
'Tigoni'	0	0.85a	11.91a	0.89a
	125	0.94b	13.09b	1.10b
	750	1.97e	11.18c	1.08c
	500	1.58g	10.54h	0.96abc
	750	1.97e	11.18f	1.08ab

*Means followed by the same letter(s) within a column of each season are not significantly different (*P<0.05*) according to DMRT

Selected Mineral Nutrient Contents of Sampled Leaf Tissues and Tubers

Leaf tissue total nitrogen content as well as phosphorous and potassium contents were significantly (P<0.05) increased by Biozyme® rate (Table 5). At the end of the experiment, N, P and K were influenced by cultivar, Biozyme® rate and season. Nutrients in tissues significantly (P<0.05) increased with increase in Biozyme® rate.

Potato tuber N, P and K contents were significantly (P<0.05) increased by both Biozyme® rate (Table 6). The highest rate of Biozyme® had the highest content of N, P and K in tubers for seasons 1 and 2. Generally, there was

high accumulation of N, P and K in season 2 compared to season 1 (Table 6).

In both seasons 1 and 2 there was more than 1% increase in plant tissue nitrogen for plants receiving 750 ml Biozyme® foliar feed as compared to control plants. Phosphorous increased by more than 100 ppm in plots receiving 750 ml/ha Biozyme® foliar feed as compared to control plants. Potassium increased by more than 9 ppm for plants receiving the 750 ml/ha Biozyme® foliar feed compared to control plants in both seasons and cultivars.

Present results agreed with those of Vernieri et al. (2005), who found that the main benefit of Biozyme® was to provide mineral nutrients for direct uptake into leaves and improve mineral nutrient uptake by roots from the soil. Similar observations were reported by Manscuso et al., (2006).

This is desirable because although many mineral nutrients and growth promoters may already be present in plants and in the soil, plants are not always able to absorb and utilize them. The constituents of Biozyme® foliar feed induce faster and vigorous development of root mass, which improves suction of previously unavailable mineral nutrients and other substances from the soil for plant use in vigorous growth and reproduction.

CONCLUSION & RECOMMENDATIONS

Biozyme® foliar feed application significantly enhances potato tuber growth and mineral nutrient uptake compared to no Biozyme® application. This study showed that Biozyme® foliar feed enhances mineral nutrient uptake, which in turn enlarges potato tubers, rendering them liable to rapid postharvest bruising and deterioration.

Excessively large potato tubers pose greater challenges in terms of handling and storage than medium sized potato tubers. The excessively large potato tubers tend to bruise easily and perish rapidly. Therefore, Biozyme® rate greater than 500 ml/ha is not recommended since it does not result in significant additional increase in tuber yield, but rather produces tubers that are overly large and not amenable to safe handling and prolonged storage.

REFERENCES

Arthur, G. D., Stirk, W. A., van Staden, J. (2003) *Effect of a seaweed concentrate on the growth and yield of three varieties of Capsicum annuum.* S. Afr. J. Bot. **69**:207–211.

Biostadt.com (2008) http://www.biosadt.com. Accessed on 7th December, 2009.

CIP (2000) CIP. *In*: C. Graves. (Ed.). *The Potato, Treasure of the Andes—From Agriculture to Culture*. CIP, Lima, Peru.

CIP (2007) Annual Report. International Potato Center, Lima, Peru.

Crouch, I. and van Staden, J. (1992) Effect of seaweed concentrate on establishment and yield of greenhouse tomato plants. J Appl Phycol **4**:291–296.

Gawroska, H., Thornton, M. and Dwelle, R. (1992) *Influence of heat stress on dry matter production and photoassimilates partitioning by four potato clones*. Amer. Potato J. **69**:653-665.

Jaetzold, R. and Schmidt, H. (1983) *Farm Management Handbook of Kenya Vol. 11/B. (Rift Valley and Central Provinces).* Ministry of Agriculture, Kenya and GTZ. W. Germany.

Kabira, J. (2002) *Linking ware potato growers with processors of French-fries in Nakuru District, Kenya.* Report of FoodNet Processing Proj., Feb-Aug 2002.

Khurana, S. M., Minhas, J. S. and Pandey, S. (2003) *The Potato: Production and utilization in subtropics*. Mehta Publishers, New Delhi, India, 445 pp.

Lesczynski, D. B. and Tanner, C. B. (1976) *Seasonal variation of root distribution of irrigated, field-grown Russet Burbank potato.* Am. Potato J. **53**:69–78

Lung'aho, B., Lemanga, B., Nyangesa, M., Gildemacher, P., Kinyae., Demo, P. and Kabira, J. (2000) *Commercial seed potato production in Eastern and Central Africa*. KARI, 140 pp.

MacKerron, D. K. L. and Jefferies, R. A. (1986) *The influence of early soil moisture stress on tuber numbers in potato*. Potato Res. **29**:299-312.

Muthoni, J. and Nyamongo, D. O. (2009) *A review of constraints to Irish potato in Kenya*. J. Hortic. Fore. **1**(7):98-102

Okalebo, J. R., Gathua, K. W. and Woomer, P. L. (2002) *Laboratory methods of soil and water analysis:* A working manual. 2nd edition. 128 pp.

Rayorath, P., Narayanan, J., Farid, A., Khan, W., Palanisamy, R., Hankins, S., Critchley, A. T., Prithiviraj, B. (2008) *Rapid bioassays to valuate the plant growth promoting activity of Ascophyllum nodosum (L.) Le Jol. using a model plant, Arabidopsis thaliana* (L.) Heynh. J. Appl. Phycol. **20**:423-429.

Shock, C., Flock, R. Eldredge, E. Pereira, A. and Jensen, L. (2006) *Successful potato irrigation scheduling. Sustainable Agriculture Techniques*. Oregon State University Extension Service. EM8911E, October 2006.

Stahlman, M. and Allen, E. (2001) *Effect of variety, irrigation and planting date on depth, rate, duration and density of root growth in potato* (*Solanum tuberosum*) crop. J. Agric. Sci. **137**:251–270.

Taylor, M., Mcdougall, G. and Stewart, D. (2007) In: D. Vreugdenhil, J. Bradshaw, C. Gebhardt, F. Govers, D. MacKerron, M. Taylor and H.. Ross (Eds.). *Potato Biology and Biotechnology - Advantages and Persectives*, pp. 525-538.

Thompson, A., J. King., K. Smith and Don, H. (2007) *Opportunities for reducing water use in agriculture*. Defra Research Project Final Report for WU0101.

Thornton, M. K. (2002) *Effects of heat and water stress on the physiology of potatoes.* Paper presented at the Idaho Potato Conference on 23th January 2002.

Vandam, J., Kooman, P. and Struik, P. (1996) *Effects of temperature and photoperiod on early growth and final number of tubers in potato* (*Solanum tuberosum* L.). Potato Res. **39**:51-62.

Vernieri, P, Borghesi, E, Ferrante, A. and Magnani, G. (2005) *Application of biostimulants in floating system for improving rocket quality.* J. Food Agric. Environ. **3**:86–88

Yuan, B., Nishiyama, S. and Kang, Y. (2003) *Effects of different irrigation regimes on the growth and yield of drip-irrigated potato*. Agricultural Water Management **63**: 153–167.

Yutaka, M., Kato, H., Muranaka, T. and Yoshida, S. (2002**)** *Amyloplast formation in cultured tobacco BY-2 cells requires high cytokinin content.* J. Plant Cell Physiol. **43**(12):1534-1541.